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14. ABSTRACT

We have performed coherent Rayleigh-Brillouin scattering (CRBS) experiments on collisional gasses subject to laser intensities beyond those considered perturbative to the gasses' thermodynamic parameters. CRBS is a four wave mixing scheme traditionally used for gas diagnostic applications when utilizing low intensity laser pulses. In these experiments high intensity laser pulses are used which yield signal lineshapes inconsistent with perturbative theory. Gas heating, weak ionization, and three dimensional effects are discussed as possible nonlinear optical effects which would have to be accounted for in order to model the high intensity regime. The cause of this altered lineshape may furthermore be used to diagnose the full effect of the laser pulses on the gas.

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THE AIR FORCE RESEARCH LABORATORY
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Coherent Rayleigh-Brillouin Scattering in High Intensity Laser Fields: Optical Lattice Gas Heating

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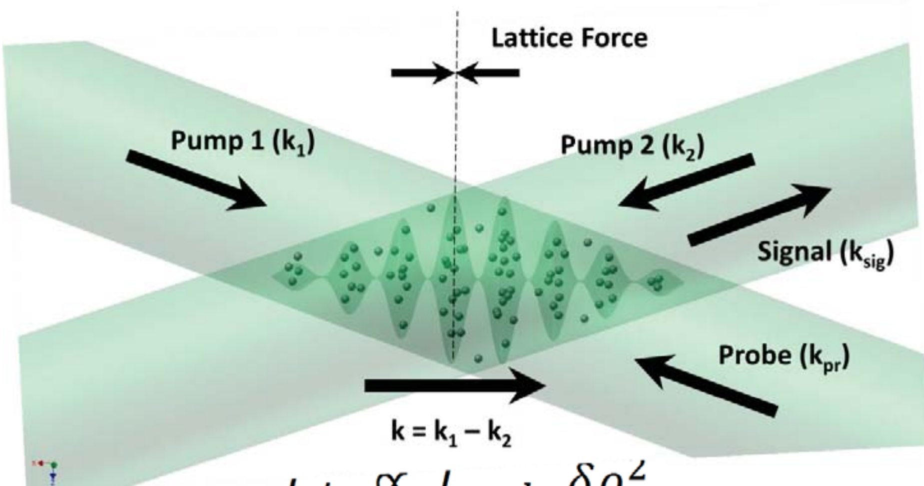
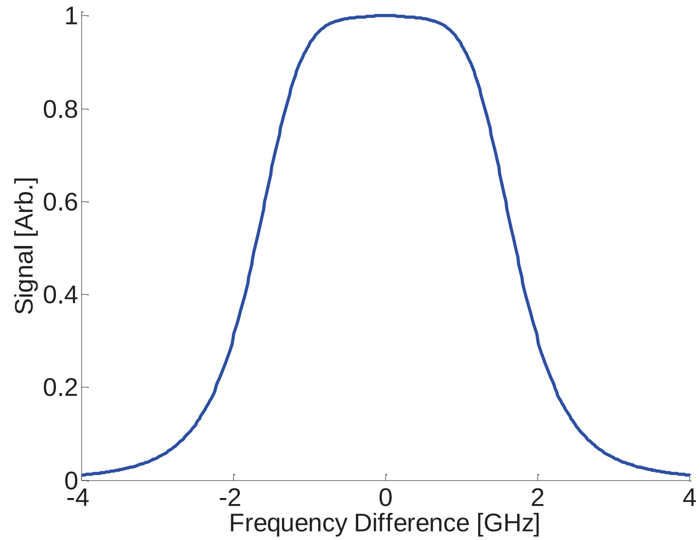
Coherent Rayleigh-Brillouin Scattering

- **Pulsed four-wave mixing scheme used for gas diagnostics**
- **Low intensity**
  - Perturbative regime (small perturbations)
  - Scattering spectra predicted by simplified gas dynamic model
- **High intensity**
  - Complex collision and forcing term
  - Cannot be predicted by simplified model (must be statistically simulated)
- **Experimentally prove gas heating via optical lattices**



$$I_{sig} \propto I_{probe}\,\delta\rho^2$$



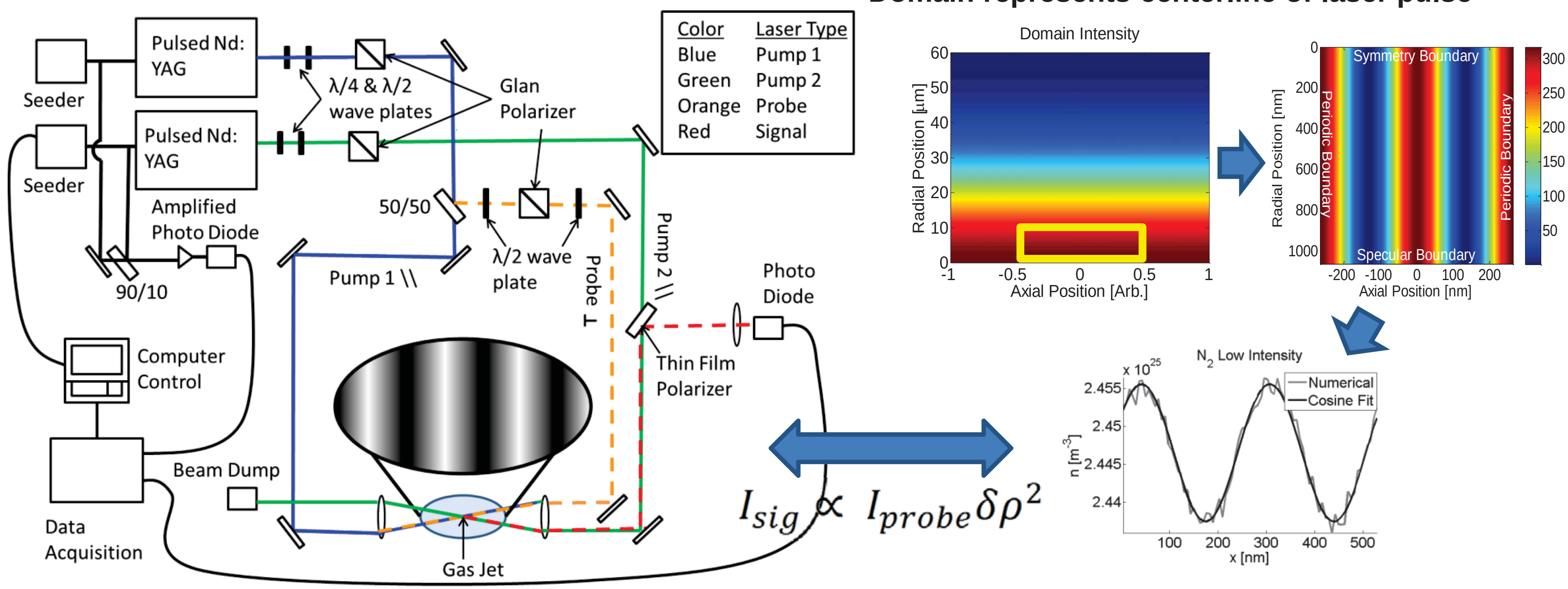
Experimental/Numerical Setup

Experimental

- Narrowband pump beams (~45 µm dia.)
- Frequency difference between pumps swept to vary lattice velocity
- Low speed gas jet placed at interaction region
- Signal magnitude measured on high speed oscilloscope

Numerical

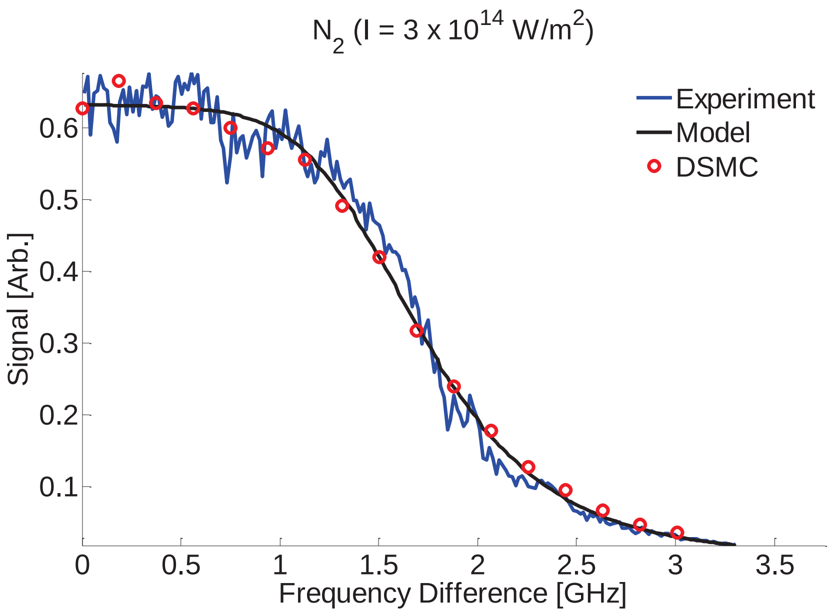
- Modified version of a DSMC code SMILE used to simulate particles within optical lattice
- Parameters chosen for direct comparison with experiment
- Density perturbation found through non-linear least squares fit
- Domain represents centerline of laser pulse



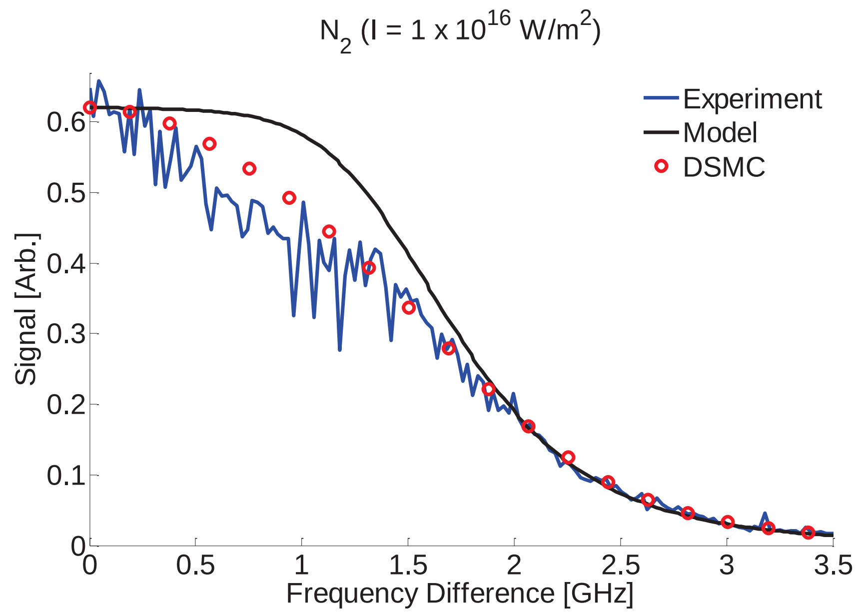
$$I_{sig} \propto I_{probe}\delta\rho^2$$

CRBS Results

Low Intensity

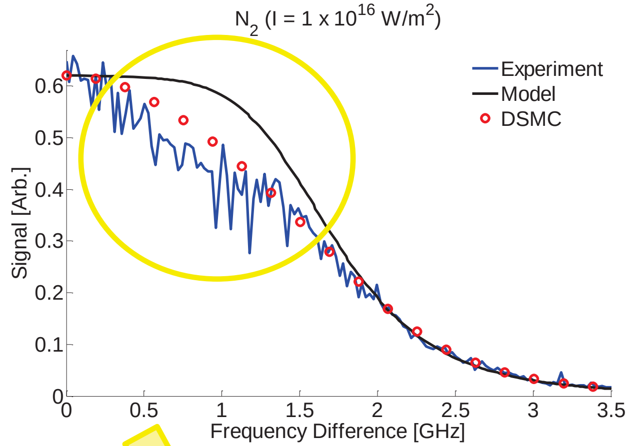


High Intensity

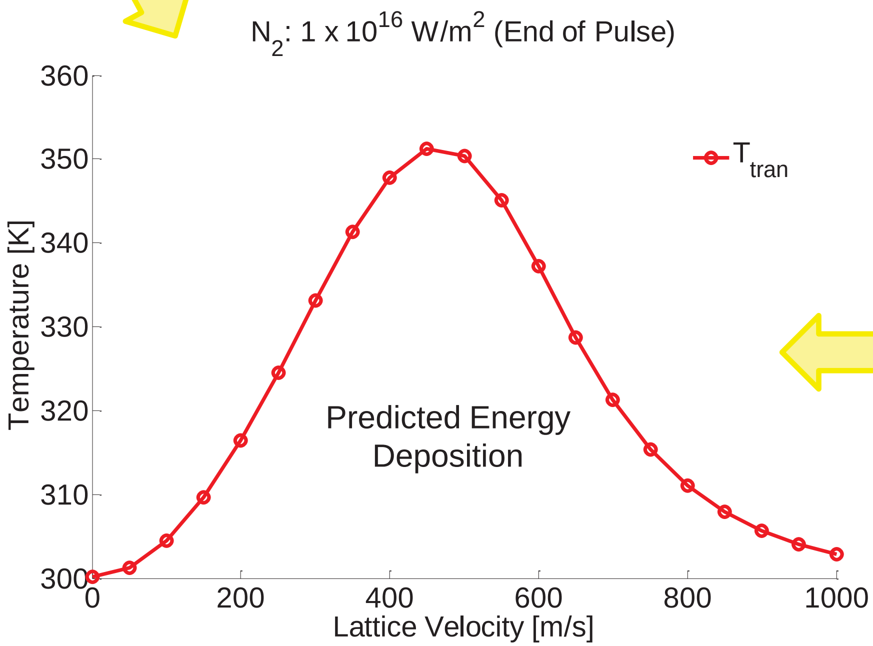


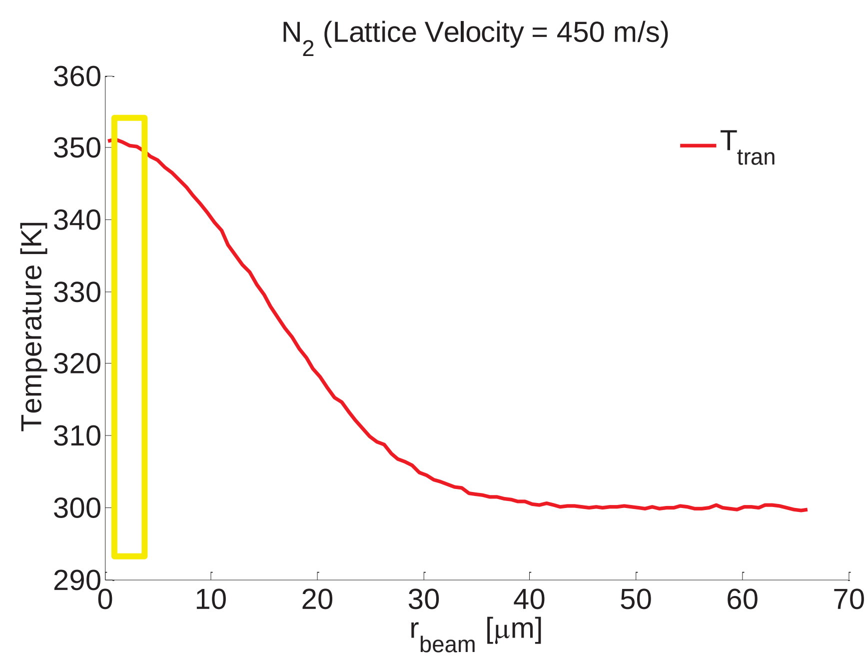
- **Experiment and DSMC show good agreement with six-moment model (s6) for low intensity**
  (X. Pan, "Coherent Rayleigh-Brillouin scattering," Princeton University (Ph.D. Thesis, 2003))
- **Possible causes of narrowing at higher intensities include:**
  - Partial ionization (not lattice velocity dependent)
  - Gas dissociation (not lattice velocity dependent)
  - **Gas heating** (lattice velocity dependent)

DSMC Heating Prediction

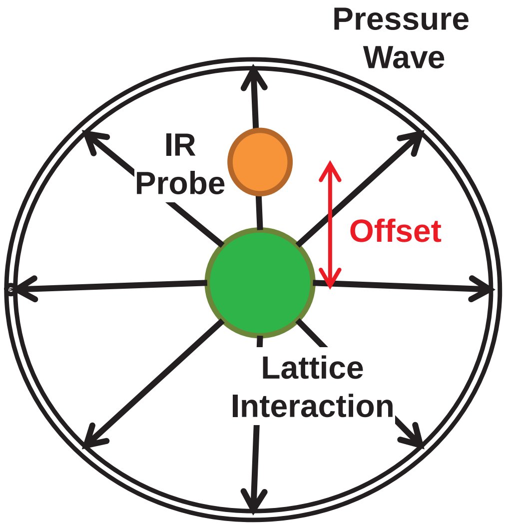


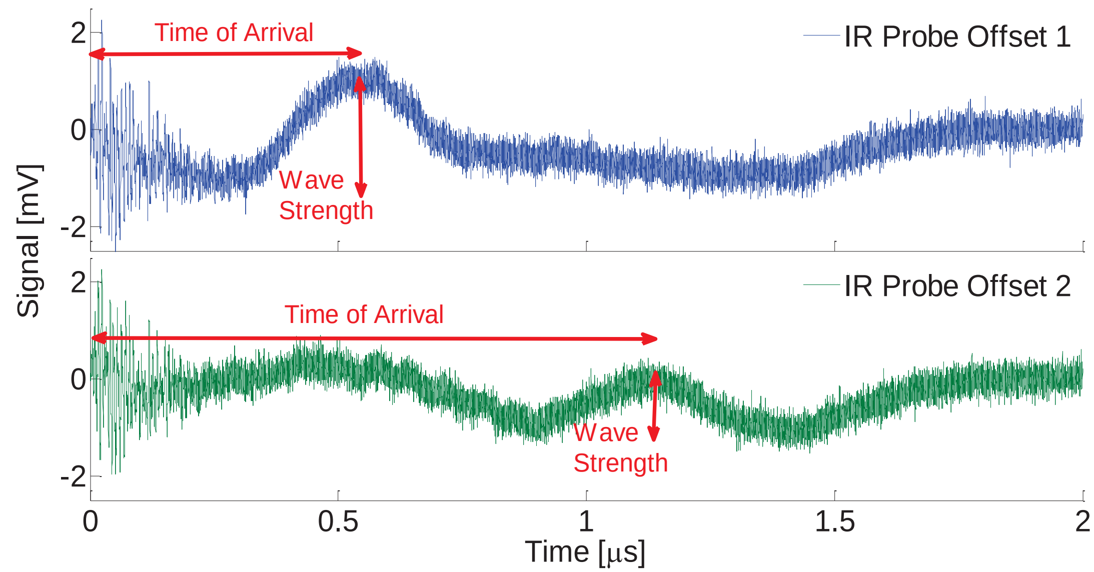
- **Peak centerline temperature increase of 51 K at lattice velocity = 450 m/s**
- **Temperature varies radially with I^2**
- **Average volume temperature (laser FWHM ~45 µm dia.) of 330 K**



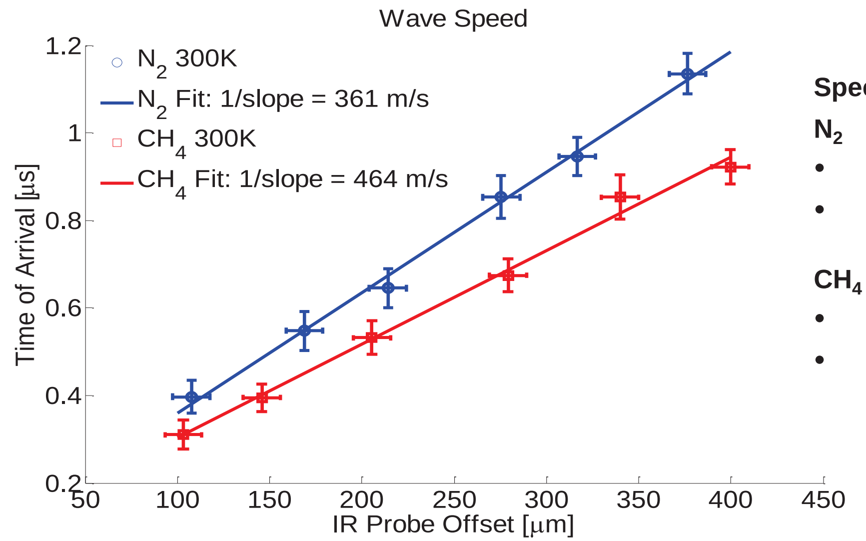


Experimental Energy Deposition





- **Detects IR probe beam deflection due to refractive index change caused by pressure wave expansion**
- **Magnitude of photodiode signal proportional to strength of pressure wave**
- **Measurements taken vs. probe beam offset and lattice velocity**



Speed of sound:

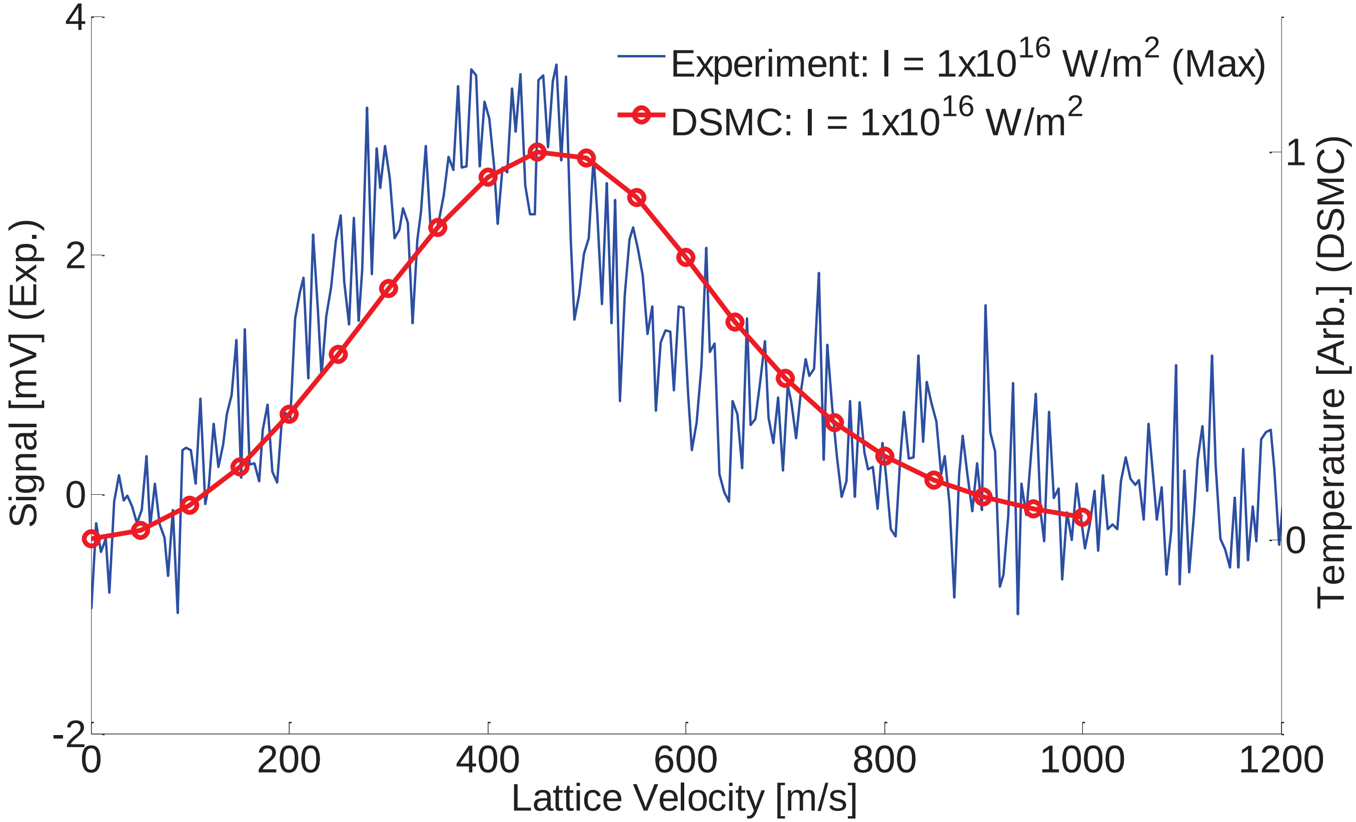
N_2

- **Calculated: a = 353 m/s**
- **Measured: a = 361 m/s (+2.3%)**

CH_4

- **Calculated: a = 450 m/s**
- **Measured: a = 464 m/s (+3.1%)**

IR Probe Results



- **Temperature profile normalized by maximum (trend only)**
- **Peak locations vary by ~40 m/s (~9%)**
  - DSMC assumes max intensity
  - Laser beam alignment
  - Pump timing

Summary

- **High Intensity CRBS effects:**
  - Partial ionization (Not lattice velocity dependent)
  - Gas dissociation (Not lattice velocity dependent)
  - **Gas heating** (Lattice velocity dependent)
- **Local gas heating shown in high intensity CRBS due to lattice interaction**
  - Numerically predicted
  - Experimentally verified by pressure wave detection with IR probe
  - Experiment and numerical simulations show good agreement